

NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY

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REPORT NO. 1102

EFFECTS OF HYPERBARIC CONDITIONS
ON CORNEAL PHYSIOLOGY
WITH HYDROGEL CONTACT LENSES

by

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and
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Naval Medical Research and Development Command
Research Work Unit MR00001.01-5104

Released by:

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Naval Submarine Medical Research Laboratory

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SUMMARY PAGE

PROBLEM

Navy divers who wear spectacles for the correction of defective visual acuity often dive either without visual correction, or with a prescription faceplate where practical. This creates the problem of storing their spectacles while diving and finding them again when they surface. Contact lenses could solve this problem. However, it is unknown what detrimental effects might occur to corneal physiology while diving.

FINDINGS

Bubbles formed toward the periphery of hydrogel (soft) contact lenses during decompression, but they did not significantly affect vision or corneal physiology, and were not noted subjectively.

APPLICATION

Provides documentation that soft contact lenses can safely be worn while diving.

ADMINISTRATIVE INFORMATION

This research was conducted as part of the Naval Medical Research and Development Command Work Unit MR00001.01-5104 - "Effects of hyperbaric conditions on corneal physiology." It was submitted for review on 21 May 1987, approved for publication on 2 October 1987, and designated as NSMRL Report No. 1102.

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ABSTRACT

Four chamber subjects wearing various hydrogel contact lenses underwent hyperbaric exposures to 150 Feet Sea Water (FSWG) with a bottom time of 30 minutes for a total of 24 lens trials. No displacement of the lenses was reported, but bubbles formed in twenty-five percent of the trials. They were not, however, noticed by the subjects and did not significantly affect vision or corneal physiology.

INTRODUCTION

There has been an explosion of interest in the undersea world. Approximately two million Americans have received scuba instruction; 50,000 of them are actively engaged in sport diving (1). Divers with refractive errors usually dive either without corrections or, if available, with prescription faceplates. Wearing hydrogel contact lenses during underwater activities with self-contained underwater breathing apparatus (SCUBA) offers visual advantages, but the risks to civilians as well as the military have been inadequately researched.

The United States Navy expects its divers to perform their specialties under a wide range of diving conditions. Each of these specialties and situations requires a different degree of visual performance. For the working diver, underwater vision is more critical than vision on the surface. So many divers who require spectacles solve that problem by wearing face-plates with bonded refractive corrections to improve their uncompensated refractive errors under water. However, Navy combat divers need to have optimum vision not only while they are in the water but also while conducting surface operations. When these men who wear face-plates with bonded corrections come to the surface, they cannot see adequately until they find and put on their spectacles.

One option for improving the vision of divers is to use contact lenses. These include standard hard (PMMA), gas permeable rigid, and hydrogel contact lenses. Clinicians for years have observed that most sport and military divers wear contact lenses without adverse effects (2,3). However, two studies have shown transient adverse effects of wearing standard hard contact lenses. Bubbles seem to occur in the precorneal tear film behind the rigid (PMMA) lenses after exposures to a hyperbaric environment resulting in corneal edema, dimpling of the corneal epithelium, and reduced visual acuity (4,5).

The bubble content in the precorneal tear film under conditions of decompression are thought to be nitrogen. As the pressure decreases, the bubbles expand. This causes the ophthalmic signs described above. Oxygen deficiency does not seem to be a factor as it is in hypobaric environments. Lens displacement, which could result in ocular injury or disruption of vision, is also of concern.

Several investigations have demonstrated the potential of hydrogel lenses for improving vision in scuba diving (1,2,6). Although one study revealed better vision and normal eye comfort when diving in fresh water, the lenses were sometimes lost when the face mask was removed (1). However, Williamson feels that lens displacement at the surface with Bionite(R) soft contact lenses is minimal and the lenses have many advantages over PMMA and spectacles for underwater use.

The purpose of our investigation was to evaluate various commercially available hydrogel contact lens designs and materials during hyperbaric exposures. This was done using low, medium, and high water content hydrogel contact lens on trained subjects in a hyperbaric chamber with high humidity.

METHOD

Subjects

The volunteer subjects were two women and two men who were qualified as hyperbaric chamber test subjects. All were myopic. Each was randomly fit with a different unmatched pair of lenses chosen from the three hydrogel types: a low water polymacon 38%, a medium water bufilcon A 55%, or a high water surfilcon A 71% water spherical content lens. Commercially available nonpreserved saline contact lens solutions were used to insert the lenses. Informed consent was obtained from the subjects after the protocol had been fully explained.

Procedure

Gas transfer and corneal responses due to the lenses were evaluated both under pressure and at the surface using a slit lamp and keratometer. The subjects' corneal lens relationship was photographed with a slit lamp camera if unusual phenomena were observed. Lens comfort was evaluated subjectively, and visual acuity was tested at the surface, pre- and post-dive, using Snellen acuity. During the hyperbaric exposures, the subjects breathed compressed air in the double-lock hyperbaric chamber. Exposure depth in the Naval Submarine Medical Research Laboratory (NSMRL) chamber was to 45.5M (150 ft) of seawater, with a 30 minute bottom time. All dives followed standard Navy air dive tables for hyperbaric exposures with decompression stops at 20 feet for eight minutes and 10 feet for 24 minutes. Subjects remained in the chamber area for 60 minutes post-dive for safety considerations and were subsequently dismissed.

Each subject performed three dives, alternating the lens type between the eyes each time. All dives were conducted with the same investigator in the chamber. The dives took place in the mornings with an inter-dive interval of 24 hours which is within the safety factor for repetitive dives as specified by the USN Diving Manual (7).

RESULTS

The subjects commented favorably on the contact lenses. They reported that their lenses felt the same or better after reaching the bottom and during the decompression phase of the dives than on the surface. No subjects reported lens displacement or visual changes throughout the dives.

The chamber investigator first observed bubbles under lenses of subjects upon reaching the first decompression stop at twenty feet. The bubbles became more numerous during travel to the surface. They were very symmetrical and progressively grew until they fractured into smaller bubbles by the time the surface had been reached. They remained under the lenses for at least 30 minutes after surfacing.

When the lenses were removed after surfacing, dimpling or indentation of the corneal epithelium was observed where the bubbles had been previously noted. One subject was examined three hours post-dive. Biomicroscopy revealed very slight dimpling of the cornea and mild fluorescein pooling where the bubbles had occurred under the lenses. This subject had the largest bubbles, but no symptoms.

Of the eight trials per lens over the three dives, bubbles formed during 4 of the 24 total trials. This was more apparent in the medium water content hydrogel lenses. The low water and high water content materials had only 1 incident of bubble formation during the trials.

DISCUSSION

All subjects thought the lenses felt the same or better after reaching the bottom and during the decompression phase of the dives than on the surface. The additional moisture in the air may cause additional hydration of the lenses; when the lenses are dryer, the fit becomes tighter.

One important finding is that no lens was displaced in any of the bubble formation incidents nor in any of the trials. For the sport diver as well as the military diver, this means that these lenses may be safely worn instead of the cumbersome modified eye-wear in the mask.

In addition, two of the subjects who wore high water content lenses showed keratometric mire distortion. We cannot explain the etiology of the distorted mires with high water content lenses on two subjects after the dive. More exposures may give more information.

Bubble formation in this study appears to relate to the phenomena noted by Simon & Bradley (5). While the greatest number of bubbles occurred with medium water contact lenses, the limited number of exposures makes it difficult to relate bubble formation to materials alone. Lens design may be a significant fact as well as corneal toricity and diameter. These variables are presently being evaluated.

These results have shown no negative effects from wearing soft contact lenses during diving. Assuming that no more serious symptoms will appear with longer and deeper exposures and with subsequent slower decompression, they suggest that these lenses are safe, and that more extensive trials may be undertaken to define the limits under which these lenses can be used.

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